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U. S. ARMY
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CRASH INJURY EVALUATION

DYNAMIC TEST OF A COMMERCIAL-TYPE PASSENGER SEAT INSTALLATION IN AN H-21 HELICOPTER

One of a Series of Reports
Pertaining to the Dynamic Crash Test of a U. S. Army H-21 Helicopter

June 1963

Contract DA 44-177-AMC-888(T)

TRECOM Technical Report 63-24

prepared by:

AVIATION CRASH INJURY RESEARCH
PHOENIX, ARIZONA
A DIVISION OF
FLIGHT SAFETY FOUNDATION, INC.
NEW YORK, NEW YORK

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This report was prepared by Aviation Crash Injury Research, a division of the Flight Safety Foundation, Inc., under the terms of Contract DA 44-177-AMC-888(T). Views expressed in the report have not been reviewed or approved by the Department of the Army; however, conclusions and recommendations contained herein are concurred in by this Command.

On 12 September 1962, an obsolete U. S. Army H-21A helicopter was remotely controlled to a crash designed to simulate a known accident configuration. Aboard the aircraft were several experiments, among them a commercial-type helicopter passenger seat. Acceleration measurements were taken at the seat floor level and in the pelvic area of the passenger dummy. Results of this experiment are reported herein and conclusions and recommendations applicable to the design, construction, and mounting of the seat are presented.

While the majority of experiments conducted under the aviation crash injury research program deal with military-type equipment, the commercial passenger seat tested in this instance was a prototype model which incorporated several new principles. The testing of these principles under dynamic conditions was considered advisable in order that applicable criteria might be transferred to the design of crew or troop seats of the future.

FOR THE COMMANDER:

KENNETH B. ABEL
Captain TC
Adjutant

APPROVED BY:

WILLIAM J. NOLAN
USATRECOM Project Engineer

Task 1AO24701A12101
(Formerly Task 9R 95-20-001-01)
Contract DA 44-177-AMC-888(T)
TRECOM Technical Report 63-24

DYNAMIC TEST OF A COMMERCIAL-TYPE PASSENGER SEAT INSTALLATION IN AN H-21 HELICOPTER

One of a Series of Reports Pertaining
to the Dynamic Crash Test of a
U. S. Army H-21 Helicopter

By

Langston W. T. Weinberg
James W. Turnbow, Ph. D.

Technical Report
AvCIR 62-25
June 1963

Prepared by
Aviation Crash Injury Research
a division of
Flight Safety Foundation, Inc.
2871 Sky Harbor Blvd.
Phoenix, Arizona

for
U. S. ARMY TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

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ILLUSTRATIONS

SUMMARY

This report presents an analysis of the crashworthiness characteristics of a commercial helicopter passenger seat as installed in a helicopter which was subjected to a full-scale dynamic crash test.

On 12 September 1962, Aviation Crash Injury Research conducted a dynamic crash test of an H-21 helicopter under contract to the U. S. Army Transportation Research Command. Included among several personnel restraint systems tested in this experiment was a prototype passenger seat built for a commercial helicopter. The two-passenger forward-facing seat was occupied on the aisle side by an anthropomorphic dummy and on the wall side by sandbags designed to simulate a second passenger.

The dummy was instrumented by accelerometers installed in the pelvic area. These accelerometers were arranged to permit recording of the impact decelerations in the longitudinal, lateral, and vertical directions. A tensiometer in the dummy's seat belt recorded seat belt force. A high-speed camera recorded the action of the seat and occupant during the entire crash sequence.

The seat maintained its structural integrity to the extent that a properly belted occupant would have been retained both in the seat and in the original location in the cabin. However, large displacements of the arms, legs, and torso of the dummy occurred with respect to the seat, implying severe buffeting of the occupant. The accelerations recorded in the dummy (25-30G lateral and longitudinal and 35-40G vertical) probably would have been survivable with moderate injury when sustained under conditions of optimum support, a condition not met in this test.

CONCLUSIONS

Based on the data presented in this report, it is concluded that:

1. This commercial passenger seat probably incorporates sufficient strength to provide retention in potentially survivable crashes of the type described in this report.

2. In this test, the floor immediately forward of the test seat buckled in such a way as to provide some longitudinal support for the seat. Only further tests or actual experience with the seat in accident situations will allow evaluation of the seat with respect to ability of the seat to withstand longitudinal accelerations when unsupported.

3. Flailing of the extremities of the dummy occupant occurred to an extent suggesting that injurious contact with other seat structures would have occurred had such seats been present.

4. The aisle leg of the seat is quite rigid and may constitute a hazard to the occupant under high vertical decelerations due to its inability to deform or to absorb energy.

5. The decelerations experienced in this potentially survivable crash would probably have caused failure of the wall attachment tube if the standard aluminum tube had not been replaced by one of steel.

RECOMMENDATIONS

Based on the foregoing conclusions, it is recommended that:

1. The folding leg of the commercial passenger seat be redesigned to incorporate energy absorption capability to reduce peak vertical accelerations.

2. The attachment of the seat to the wall of service aircraft be capable of developing the full potential of the seat. The standard troop seat attachments in the H-21 are inadequate from this standpoint.

3. Additional restraints in the form of shoulder harnesses be installed.

4. Provision be made for reducing injury through contact of the lower extremities with the rear main beam of the seat in all installations involving tandem seating.

INTRODUCTION

The commercial passenger seat utilized in this dynamic crash test was supplied to AvCIR by an aircraft manufacturer contemplating use of this seat in a helicopter currently in commercial service. The seat was built in accordance with Federal Aviation Agency specifications.

Federal Aviation Agency regulations covering seat design specify the required strengths in longitudinal, lateral, and vertical directions. Proof that these requirements have been met by a given installation is generally obtained by static test. In fact, no requirements have been established for dynamic tests, even though it has been demonstrated that static tests do not satisfactorily replace tests conducted under dynamic conditions.

AvCIR conducted a full-scale dynamic test of the seat on 12 September 1962. The seat was mounted in the passenger compartment of an H-21 test vehicle. The H-21 was remote controlled through its flight regime to the desired crash conditions.

TEST OBJECTIVES

The objective of the test was to evaluate the crashworthiness of a commercial helicopter passenger seat in a full-scale dynamic crash test. Particular areas of interest were the adequacy of the tiedown of the seat to the basic structure and the manner in which the crash forces were transmitted to the seat occupants.

DESCRIPTION OF TEST ARTICLE

The commercial helicopter passenger seat used in this test was a two-passenger forward-facing seat. The basic structure of the seat consisted of a welded aluminum tubular frame. The frame was supported on the fuselage side by a horizontal bar attached to the fuselage wall and on the aisle side by a vertical leg. The seat was bolted to the horizontal bar by means of eyebolts to allow the seat to be folded against the wall when not in use. Individual seat-pan cushions were supplied for the occupants. These cushions consisted of a thin aluminum frame with a foam-rubber pad covered by fabric. A single back rest served both seats. The back rest folded onto the seat pan for stowage. This folding back rest provides a "break-over" feature in the event of a sudden deceleration such as a crash. The aisle support leg was bolted to the tubular structure of the seat and was designed to disconnect from the floor and fold to the bottom of the seat pan when the seat was not in use. Several sketches and photographs, including Figures 1, 2, 3, 10, 11, and 12, show this seat and the attachments.

The seat was installed in the H-21 test vehicle to simulate installation in the commercial helicopter for which it was intended. Some changes were made to the H-21 structure to ensure a valid test of the seat structure proper rather than of the H-21 structure itself. These modifications, described below, must be considered when extrapolating the performance of the seat as reported to other installations. The normal wall attachments of the seat were connected to a 1-1/4-inch O. D. tube which was, in turn, attached to the basic aircraft structure. The use of similar tubes as a means of connecting seats to the airframe has been widely practiced by the military. These tubes, normally of aluminum, have proved to be a weak point during a crash due to insufficient strength in the vicinity of points where holes have been drilled for attachment to the airframe and attachment of seat belts. Consequently, to ensure that the commercial helicopter would be given a valid test, the conventional aluminum tube in the H-21 was replaced by one of 4130 steel. Figure 2 shows a rear view of the commercial passenger seat as installed in the H-21.

The leg on the aisle side of the seat was connected to a plate on the floor and incorporated a quick disconnect to facilitate folding of the seat. The plate itself was made of two metal flanges bolted together through the honeycomb floor. This can be seen in Figure 2. The installation was similar to that proposed for in-service aircraft.

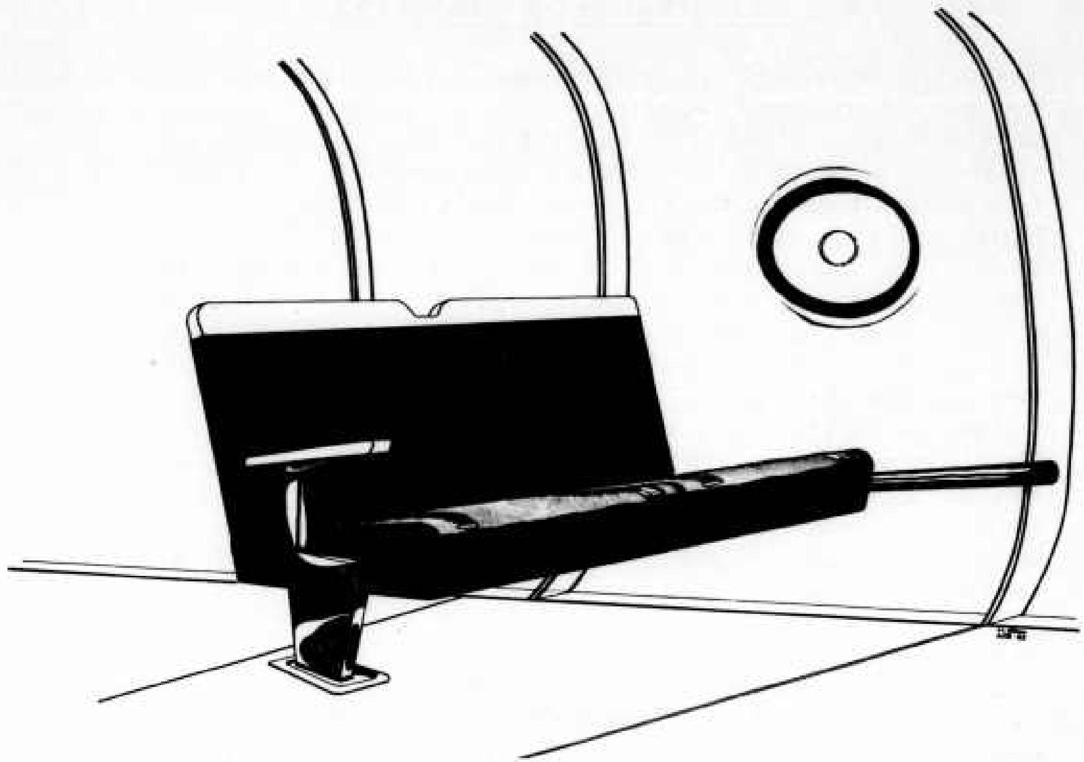

Figure 1. Sketch of Commercial Passenger Seat.

Individual seat belts were provided for the passengers. The seat belt attachments as provided on the seat were used.

Figure 3 shows the seat installed. The dummy on the aisle seat was a 95th percentile anthropomorphic dummy. The wall seat was occupied by three sandbags designed specifically for this application. They were 4-inch diameter cylinders, 36 inches long, each filled to 40 pounds. The 120 pounds was chosen only to simulate a lighter passenger in the wall seat.

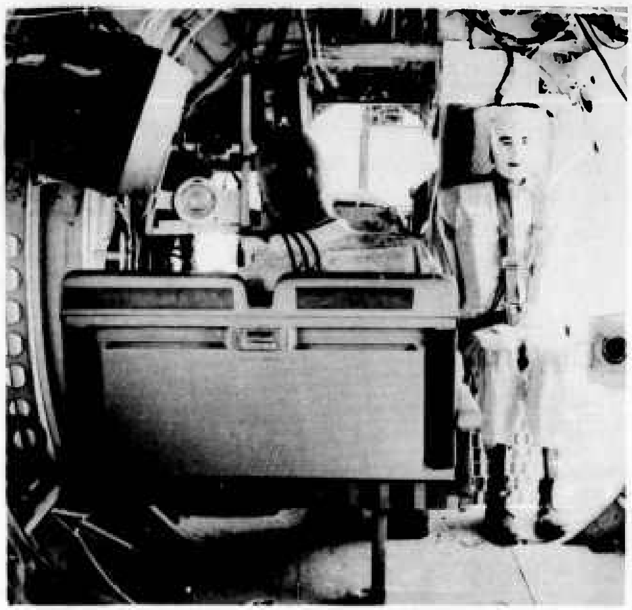

Figure 2. Rear View of Commercial Passenger Seat, Installed. Arrow shows 1-1/4-inch O. D. x 0.125-inch wall SAE 4130 tube used for support of outboard end of seat.

Figure 3. Front View of Seat, Showing Anthropomorphic Dummy and Sandbags.

TEST PROCEDURE

DESCRIPTION OF TEST OPERATIONS

The test vehicle used in this experiment was an H-21 helicopter. A drone control system was installed in the helicopter to allow complete remote control of the helicopter through the entire test flight. The actual flight flown during this test followed the profile shown in Figure 4.

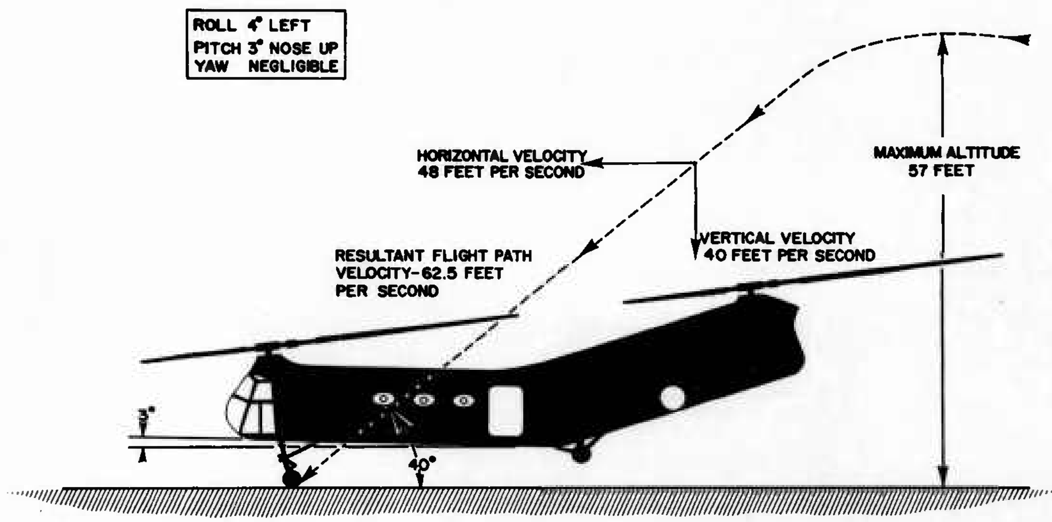

Figure 4. Diagram of Test Conditions.

A report covering the more detailed mechanics of the test operation is being prepared at this time for release at a later date.

INSTRUMENTATION

A list of the data acquisition system components related to this commercial seat experiment is presented in the table on the following page.

INSTRUMENTATION

Device	To Provide	Location	Specification
High-Speed Motion Picture Camera	Displacement time for helicopter and dummy kinematics data	4 on ground 1 on aircraft	Photosonics 1B high G tolerance, 500 fps 16mm Ektachrome ER430
Normal-Speed Motion Picture Camera	General photographic coverage	4 on ground	2 Kodak 16mm 64 fps, 2 Bolex 16mm 24 fps, Kodachrome II
Electrical Accelerometers	Acceleration sensing	3 in dummy 3 on cabin floor	Statham A5A-50-350 and A5A-100-350
Tensiometer	Force sensing	1 each in seat belt	AvCIR 2500-lb. load link
Recording Oscillograph	Amplitude-time records of transducer outputs	4 each at ground control point	CEC Model 5-114-26, Channel recording oscillograph with related power supplies
Photographic/ Oscillographic Data Correlation Device	Zero time for camera film and oscillograph record	2 each	Photo flash bulbs mounted in field of view of cameras. Firing pulse to bulbs recorded on oscillograph record for correlation
Voltage Generator	Timing for high-speed cameras	Ground Control point	115 Volt AC generator, 60 cps timing pulse
Fairchild Flight Analyzer	Horizontal and vertical speed of the helicopter	500 feet perpendicular to center of flight path	FDFA-044

The accelerometers and force tensiometers were connected through a balance and sensitivity unit to a 500-foot umbilical cable which was connected directly to recording oscillographs located at a stationary point on the ground. A block diagram of the instrumentation system is presented in Figure 5.

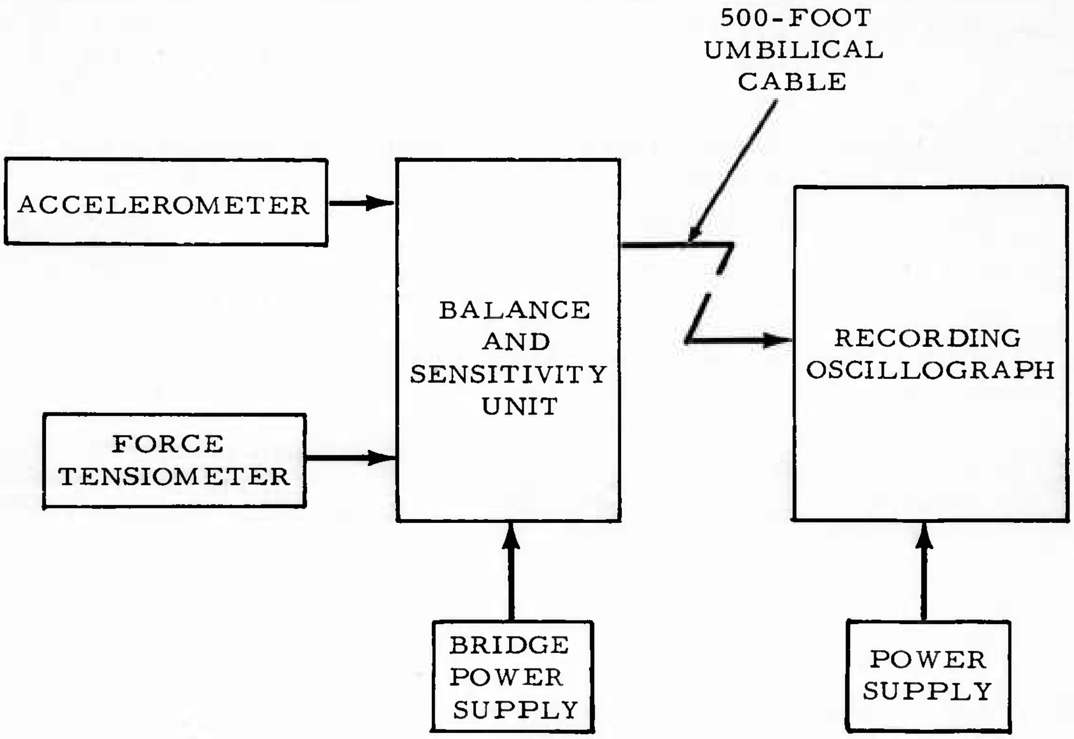

Figure 5. Instrumentation Data Recording System.

Just prior to the test, an eight-step resistance calibration was made on all appropriate channels by connection of a calibration unit to the balance and sensitivity unit on the helicopter. The bridge battery voltage was monitored on one channel to record any change in the bridge voltage during the crash sequence. No voltage change was recorded.

The high-speed camera and associated auxiliary lighting were controlled by a switch on the master control panel at the control point. During the descent, the cameras and lights were turned on manually by the instrumentation operator, and they were automatically turned off after a 10-second period by a time delay circuit.

The high-speed camera (No. 2 in Figure 6) was located approximately 4 feet in front of the seat and focused on the dummy. The other cameras and details given in Figure 6 were associated with other experiments conducted during the flight and are not discussed in this report.

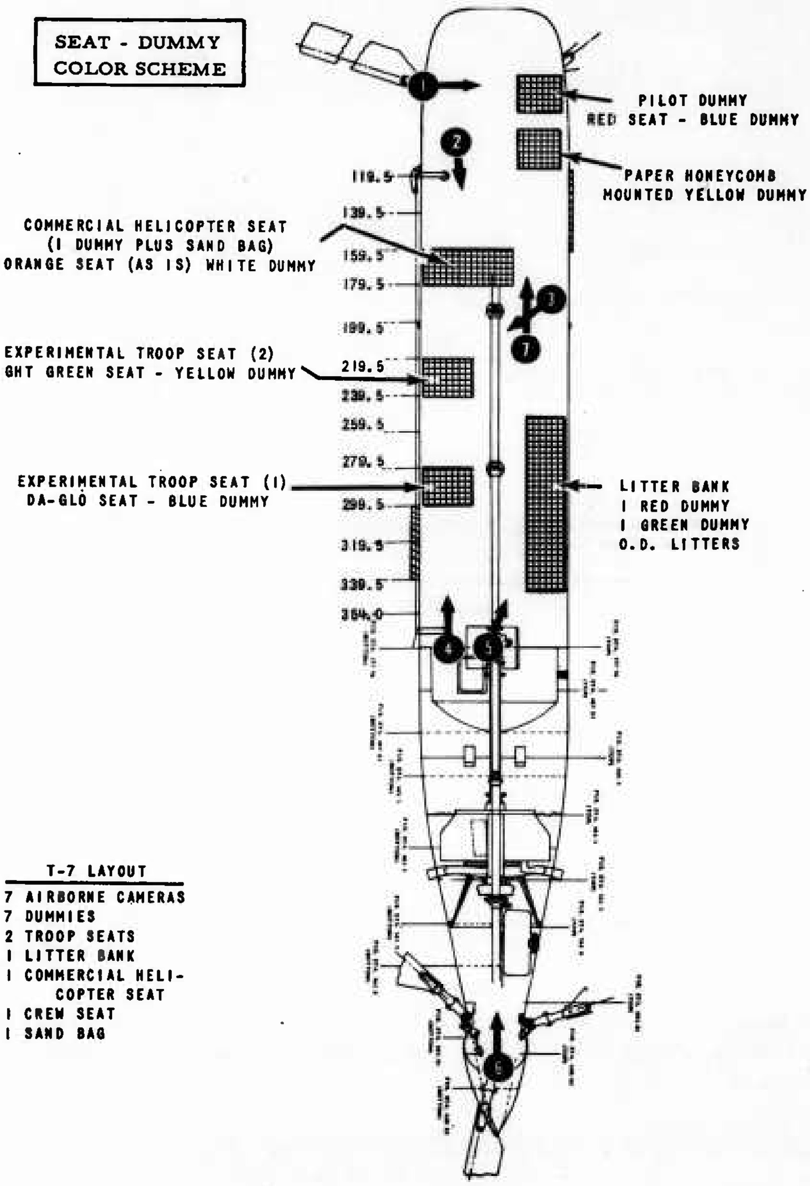

Figure 6. Camera Placement Diagram.

TEST RESULTS

FUSELAGE STRUCTURE

Figure 7. View of H-21 Test Vehicle, Postcrash. The general location of the commercial passenger seat is shown by arrow.

The entire lower structure of the forward fuselage section, including fuselage skin, floor support structure, and lower section of body frames, was crushed by impact of the helicopter on the runway. The left side of this lower structure was crushed more severely than the right side, due to impact with approximately 4 degrees left roll. Interior views showing the extent of buckling of the floor panels throughout the cabin area are given in Figures 8 and 9.

Generally, the fuselage structure above the normal troop seat attachment points, approximately 17 inches above the floor line, remained intact on both sides of the aircraft, while structure below this line was crushed extensively.

Although this impact was sufficiently severe to cause irreparable damage to almost every component of the aircraft, the crash is classified as potentially survivable because the occupiable areas of the fuselage remained essentially intact.

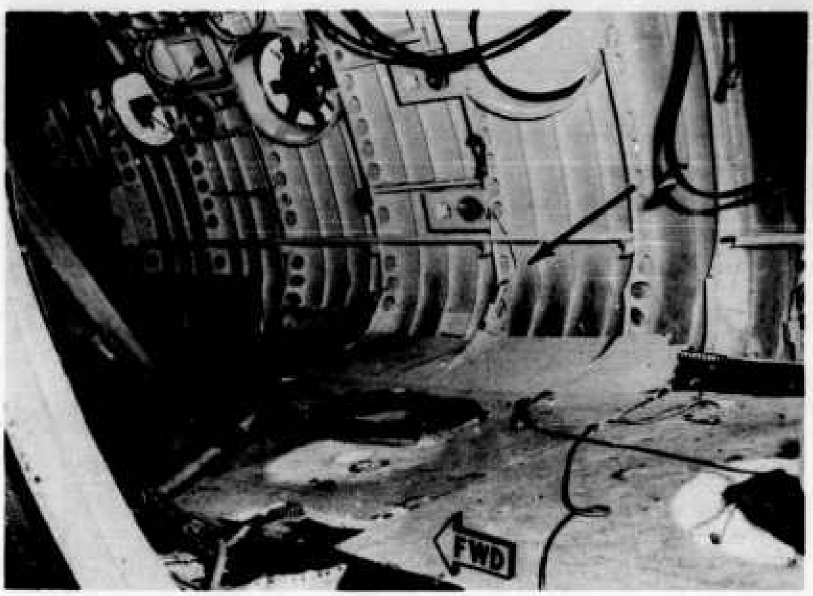

Figure 8. Passenger Compartment, Rear.
Arrow shows the buckling of fuselage frames.

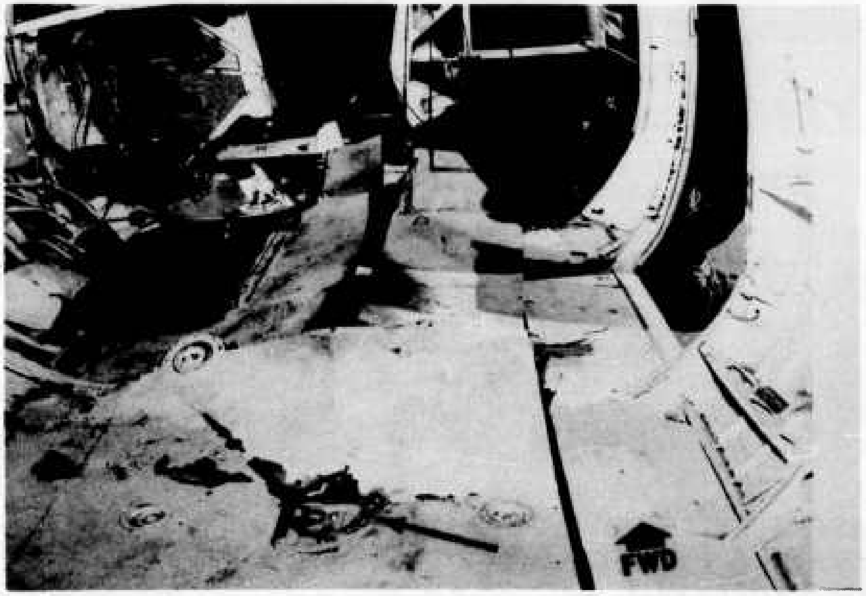

Figure 9. Passenger Compartment, Front, With Commercial Passenger Seat Removed.
Arrow shows floor attachment plate for seat.

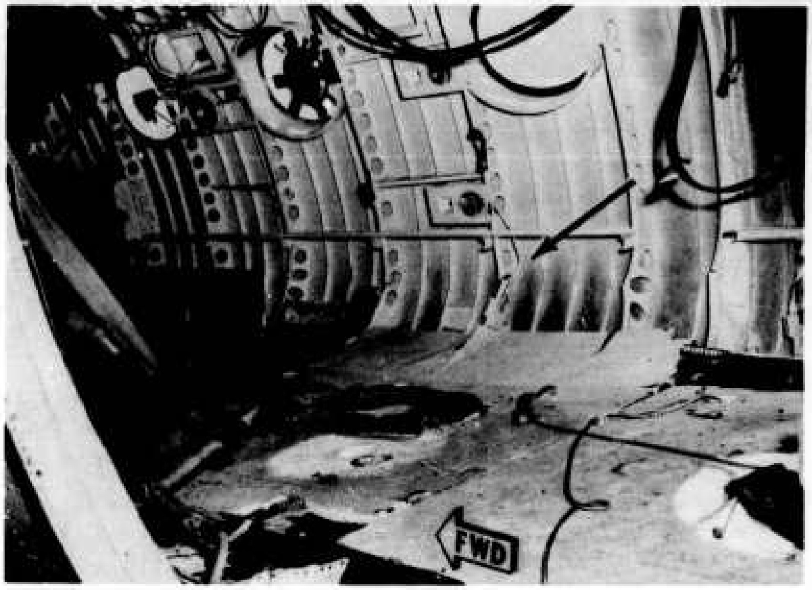

Figure 8. Passenger Compartment, Rear.
Arrow shows the buckling of fuselage frames.

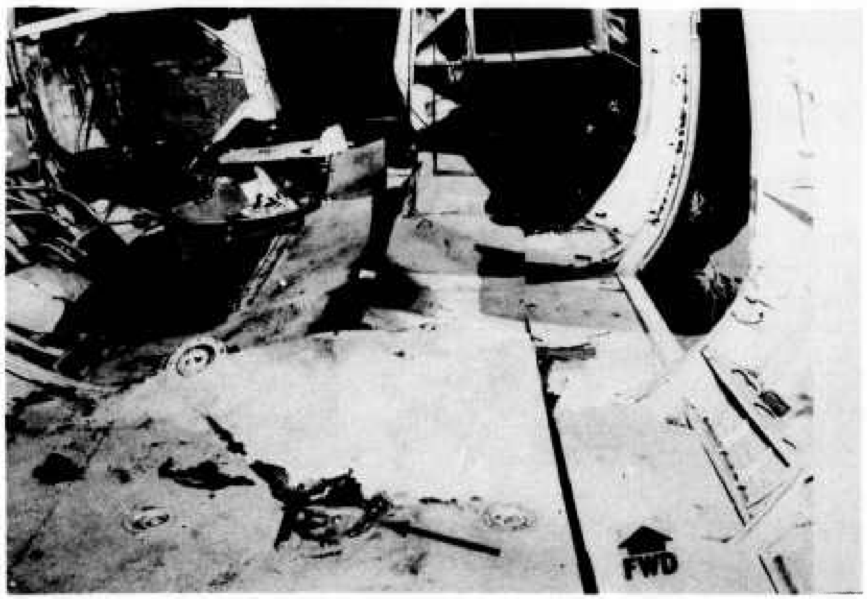

Figure 9. Passenger Compartment, Front, With Commercial Passenger Seat Removed.
Arrow shows floor attachment plate for seat.

SEAT STRUCTURE

Figures 10 and 11 show postcrash views of the seat and dummy. The seat was basically intact; however, there was considerable deformation in most elements of the seat, as shown in Figure 11. Partial separation of several parts of the seat occurred, although no complete failures of any component of the seat were observed.

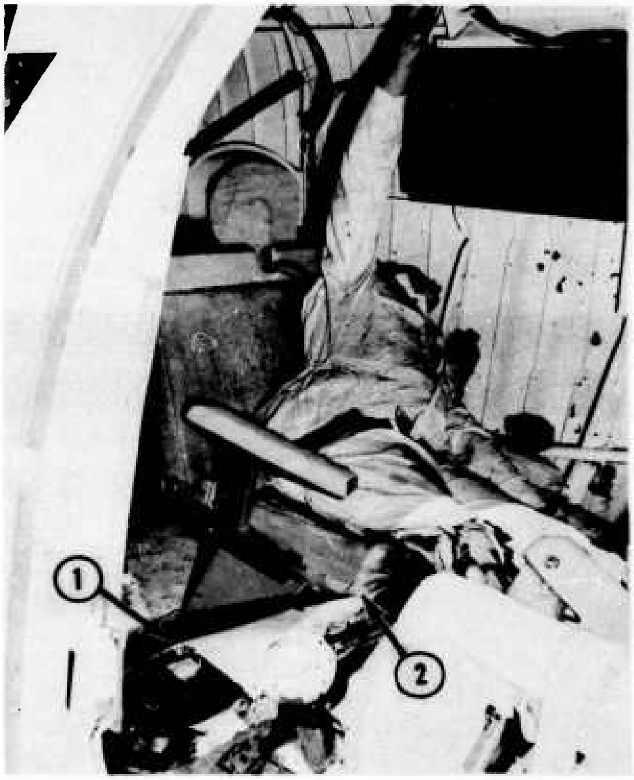

Figure 10. Postcrash View of Commercial Passenger Seat and Dummy.
Arrow 1 shows floor and supporting structure upset in front of seat by nose wheel and nose gear. Arrow 2 shows contact of seat with buckled floor structure.

Figure 11. Postcrash View of Commercial Passenger Seat, With Dummy and Sandbags Removed.
Arrow shows contact of forward edge of seat with buckled floor structure.

Figure 12 shows a postcrash view of the bottom of the seat, illustrating the deformation in the main structure. There was a fracture of the rear tube at the wall end.

Both the front and the rear tubes were bent at the center (arrow 1). In addition, the front tube was further bent near the leg of the seat. This bend occurred directly beneath the dummy. Note that the seat pan is fractured in the same area (arrow 2). The front tube has a larger permanent vertical deflection than the rear tube, as would be expected in accidents having forward and downward velocity components at primary impact; i. e., the forward tube can be expected to carry a major portion of the vertical inertia load.

Figure 13 shows the condition of the wall attachment portion of the seat. Arrow 1 shows the fracture of the rear tube. The bent flange (arrow 2) was a support for a locking bar used in folding the seat. This bar was removed prior to the test to allow modification of the test seat (an early model) to conform strengthwise to the proposed

service model. The 4130 tube to which the seat was attached at the wall of the aircraft remained in place, with slight (5 degrees or less) bends in the vertical and horizontal planes containing the axis of the bar.

Figure 14 shows the folding leg of the commercial passenger seat. Arrow 1 shows the deformation and fracture of the aft leg fitting beneath the seat. Arrow 2 indicates the area of contact of the forward edge of the leg with the buckled floor panel. (See also Figures 9, 10, and 11.)

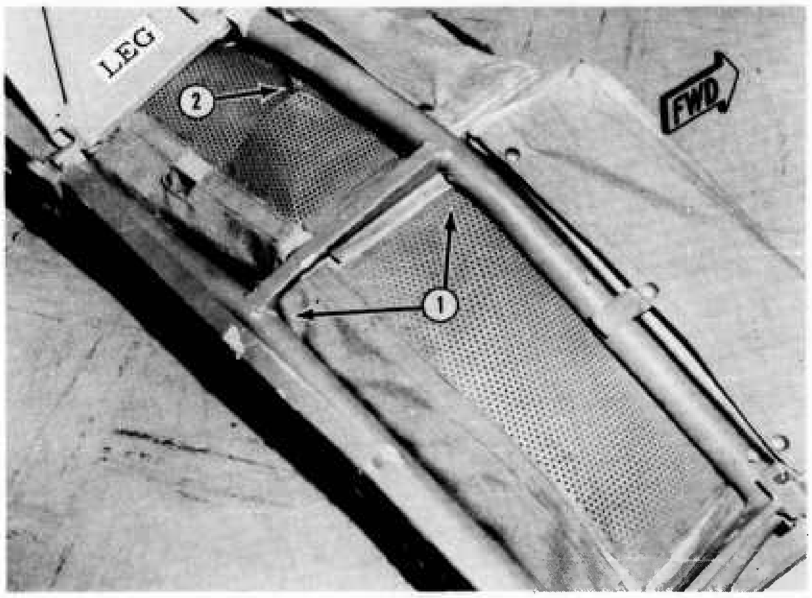

Figure 12. Bottom Structure of Seat, Postcrash.

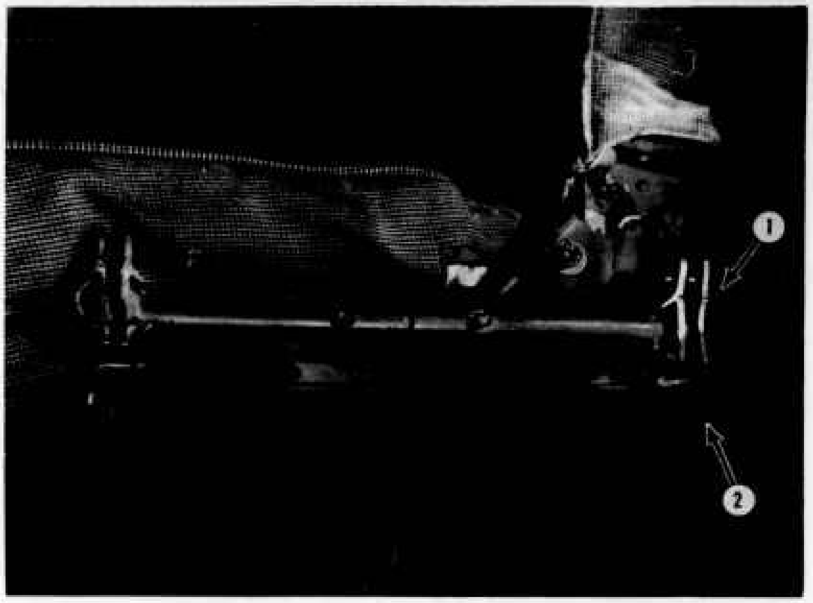

Figure 13. Wall Attachment, End of Seat, Postcrash.

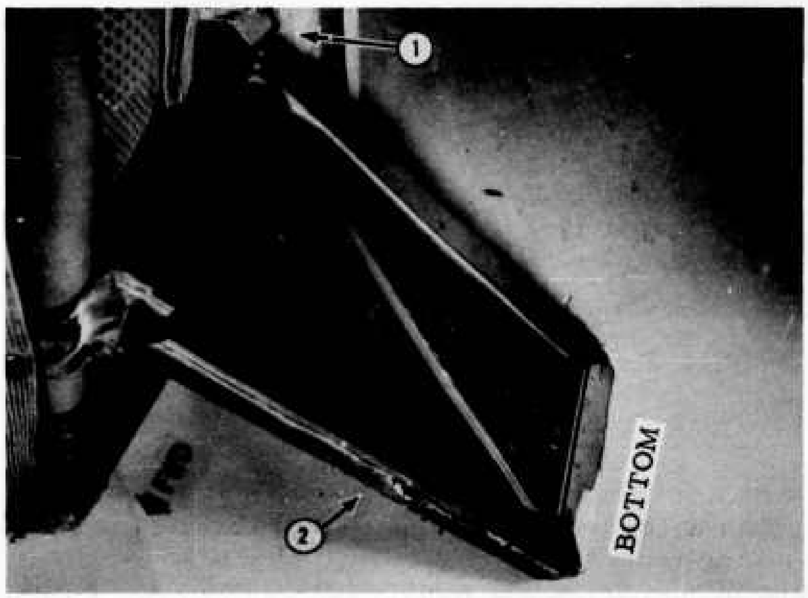

Figure 14. Folding Leg of Commercial Passenger Seat. Arrow 1 shows a partial failure of the fitting. Arrow 2 shows region of contact of leg with buckled floor.

Figure 15 gives an overall rear view of the orientation and condition of the seat immediately after the crash. Arrow 1 shows the region of application of vertical inertia load due to the passenger in the aisle position. The position of the seat leg provides an almost direct load path to the floor. Thus, had the 200-pound dummy and the 120-pound sandbags been reversed in position, it is probable that a more extensive deformation of the forward main tubular structure would have resulted. Initially, the leg of this seat was vertical, as shown in Figures 2 and 3. The apparent rightward shifting of the floor attachment for the leg at arrow 2 in Figure 15 was actually due to the displacement of the left wall of the aircraft to the left with respect to the centerline of the floor. This movement was due to extensive buckling of the fuselage frames along the entire left side of the cabin, as shown at arrow 3.

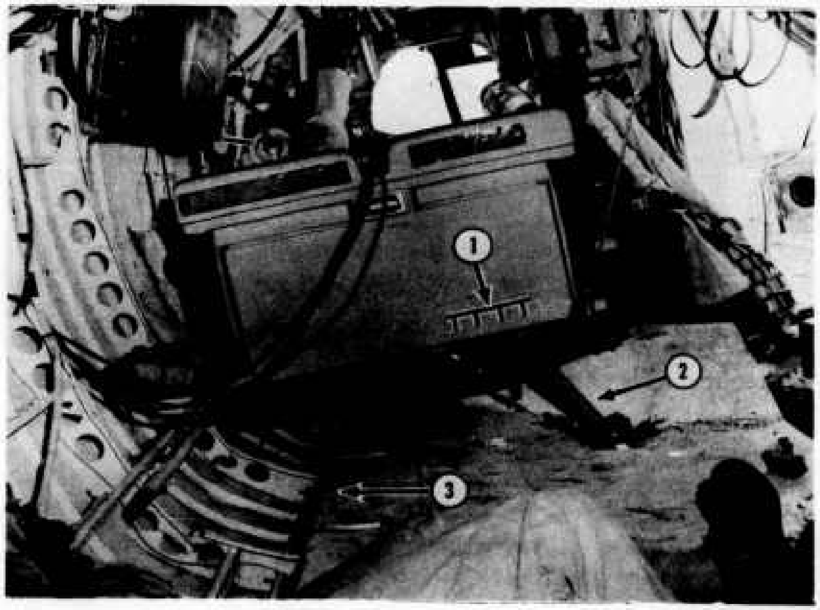

Figure 15. Rear View of Seat, Postcrash.

ACCELEROMETER RECORDS

The accelerometer traces applicable to analysis of the commercial passenger seat described in this report are presented in Figure 16, including (a) the records of lateral, longitudinal, and vertical acceleration in both the pelvic region of the dummy and at the passenger cabin floor level and (b) the passenger seat belt force. In these records, time zero corresponds to first contact of the aircraft as noted on Figure 16C. The primary seat deformation and the buckling of the floor reached maximums at about 0.215 second.

It is possible, and even probable, that the contact of seat and floor structure as seen in Figures 10 and 11 may have provided some longitudinal support to the seat, yet the performance of the seat must be considered as excellent in view of the existing specifications to which the seat is designed.

It should be recalled that the wall support of this seat was quite rugged (1/8-inch wall x 1.25-inch O.D. SAE 4130 tube), yet it was permanently deformed with approximately 5 degrees of bend in each of two planes. Failure of the normal H-21 aluminum support would have undoubtedly occurred as has been shown by previous experience with troop seats. *

The seat belt loads, Figure 16G, did not exceed 300 pounds. This is in agreement with results obtained in other tests** in which the longitudinal deceleration occurs only in conjunction with a simultaneous and relatively large vertical deceleration.

The extent of probable injury to a human occupant of the test seat can be obtained only through considerable extrapolation of the data obtained; however, these comments are pertinent:

1. The sinusoidal acceleration pulse of 33 peak G with 35 milliseconds duration would, even with optimum body support, produce minor to severe injuries to the human. ***

2. Optimum support was not provided the dummy occupant by the seat belt restraint system.

3. The lateral and longitudinal accelerations sustained would not alone have produced injury.

4. The flailing arms and legs would have come in contact with other seats in a normal density spacing.

5. Contact of the flailing legs of an occupant would be on the hard basic structure of the seat immediately to the front of the occupant.

---

* Turnbow, J. W., Ph.D., Rothe, V. E., Bruggink, G. M., and Roegner, H. F., Military Troop Seat Design Criteria, TCREC Technical Report 62-79, Aviation Crash Injury Research, Phoenix, Arizona, November 1962.

** Turnbow, J. W., Ph.D., U.S. Army H-25 Helicopter Drop Test (Preliminary Report), TREC Technical Report 60-75, Aviation Crash Injury Research, Phoenix, Arizona, December 1960.

*** Pesman, G. J., Eiband, A. M., Crash Injury, NASA Technical Note 3775, National Aeronautics and Space Administration, Washington, D.C., November 1956.

DISCUSSION OF TEST RESULTS

Figures 16A, B, and C show the acceleration environment in the crash as recorded by three accelerometers mounted in the dummy pelvic region. It should be noted that the acceleration in a given direction (vertical, lateral, or longitudinal) refers to the direction measured with respect to the dummy pelvis, not to the airframe on the ground. Considerable movement of the dummy (including flailing of arms and legs) occurred with respect to the airframe, and thus the "vertical" alignment of the vertical accelerometer at impact was not maintained during the progress of even the primary pulse. Figure 17 has been presented for the convenience of the reader in visualizing this motion of the dummy. Such displacements gave rise to interactions between the lateral, vertical, and longitudinal inputs as picked up by the respective accelerometers.

Reference to Figure 16C shows that the primary "vertical" acceleration in the dummy occurred in the interval from 0.14 second to 0.22 second immediately following the impact of the fuselage proper with the runway.

Observation of high-speed films from on-board cameras shows, as noted in Figure 16C, that during this interval the floor in the vicinity of the seat underwent the deformation shown in Figures 10 and 11, and that the dummy seat and dummy itself (Figure 17) underwent maximum displacement. Two separate pulses are evident in Figure 16C, i.e., a half sine wave in the interval from 0.15 to 0.19 second, followed by a smaller pulse at 0.21 second. An average of about 33G was maintained for some 0.025 second, accounting for a change in velocity of about 26 feet per second. The recorded "vertical" pulse would have probably been somewhat greater had the dummy remained truly vertical throughout the impact. The recorded "lateral" and "longitudinal" accelerations were more of an oscillatory nature, as seen in Figures 16A and B.

The acceleration pulse occurring at 0.215 second and recorded on all three accelerometers was probably associated with the contact of the seat with the buckled floor structure as shown in Figures 10, 11, and 14. Although no definite proof of this fact exists at this time, it is reasonably certain as observed in the high-speed films. Sign conventions are in accordance with those recommended by C. F. Gell, M. D., D. Sc., in December 1961, Issue of Aerospace Medicine, Vol. 32, No. 12, i.e., Eyeballs Right (lateral), Eyeballs In (horizontal), and Eyeballs Down (vertical).

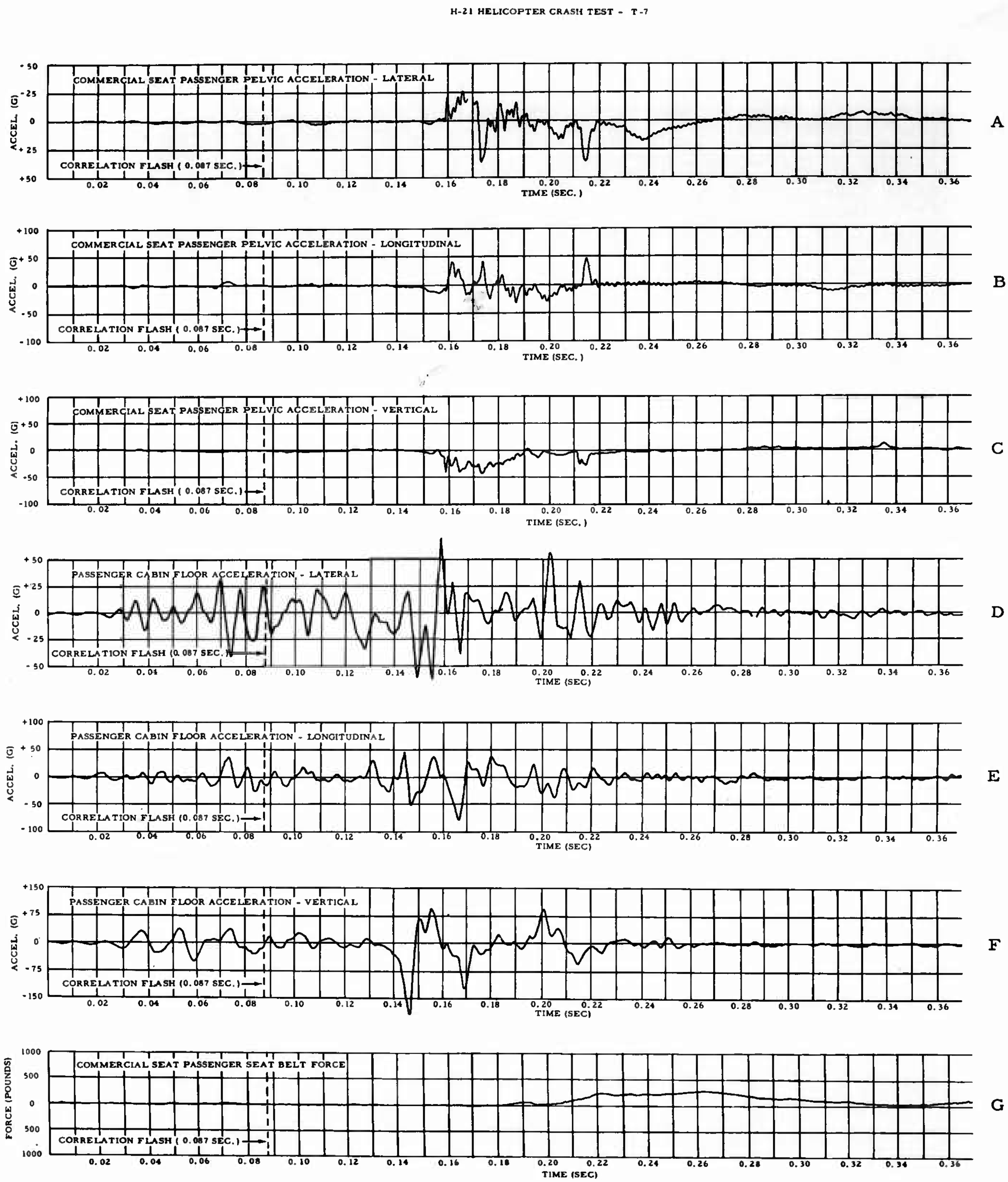

Figure 16. Accelerometer-Time and Force-Time Histories.

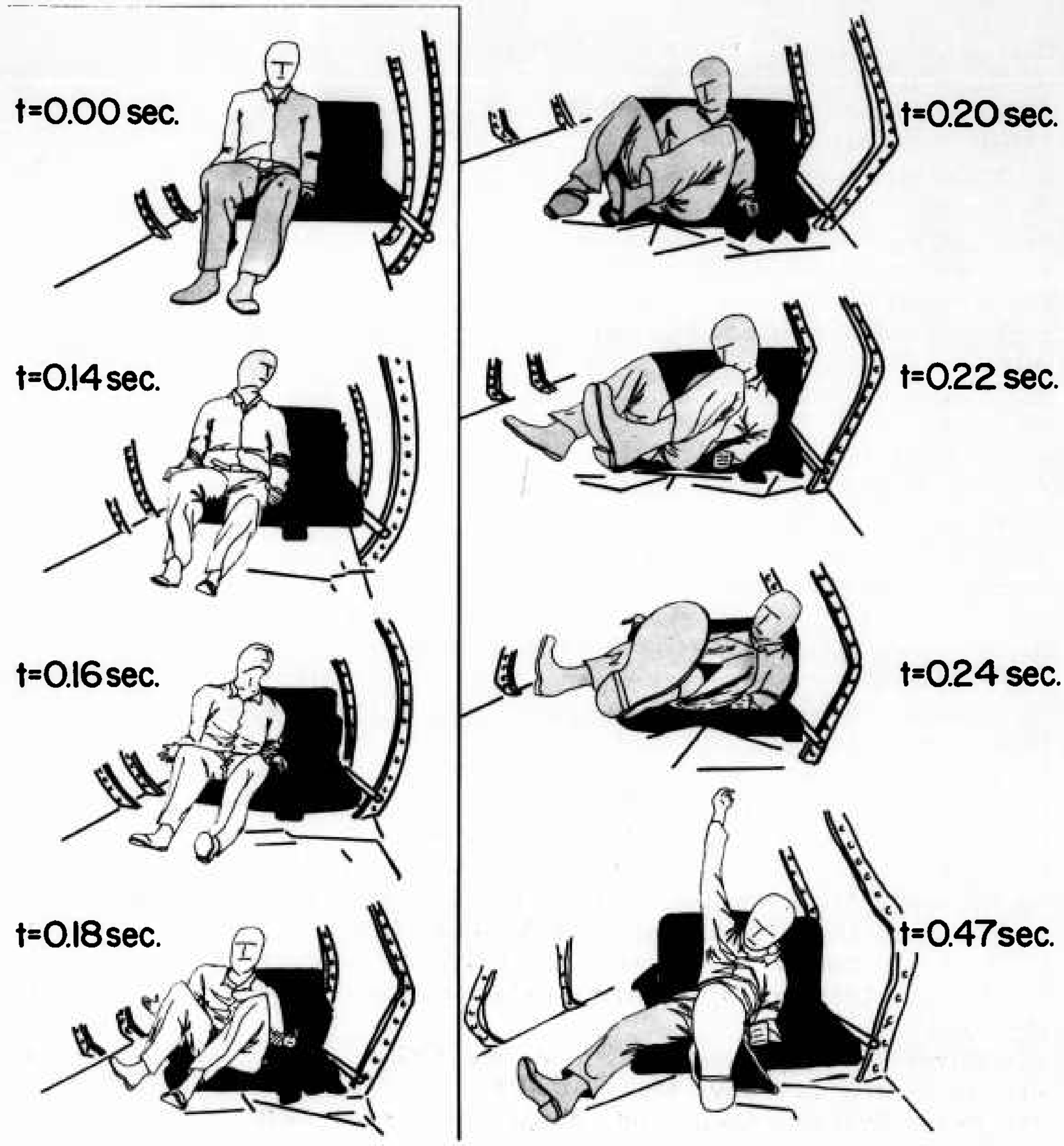

Figure 17. Kinematic Sketch of Seat and Dummy.

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David Taylor Model Basin	1
Hq, U. S. Marine Corps	2
Marine Corps Landing Force Development Center	1
Marine Corps Educational Center	1

U. S. Coast Guard	1
Canadian Army Liaison Officer, U. S. Army Transportation School	3
British Army Staff, DAQMG (Mov & Tn)	4
National Aviation Facilities Experimental Center	3
Langley Research Center, NASA	4
Manned Spacecraft Center, NASA	1
Lewis Research Center, NASA	1
NASA Representative, Scientific and Technical Information Facility	2
U. S. Government Printing Office	1
Defense Documentation Center	10
U. S. Army Medical Research & Development Command	2
U. S. Army Medical Research Laboratory	2
Human Resources Research Office	2
Director of Army Aviation, ODCSOPS	3
Aviation Safety Division, ODCSOPS	2
Director of Safety, ODCSPER	1
U. S. Army Materiel Command Aviation Field Office	2
Aviation Medicine Safety and Flight Training Branch, Bureau of Medicine and Surgery	2
Aviation Medicine Technical Division, Bureau of Medicine and Surgery	1
The Surgeon General	5
Armed Forces Institute of Pathology, Walter Reed Army Medical Center	2
U. S. Air Force Directorate of Flight Safety Research, Norton AFB	1
U. S. Army Board for Aviation Accident Research	5
U. S. Army Aviation Human Research Unit, USCONARC	1
U. S. Naval Aviation Safety Center, NAS, Norfolk	3
Naval Air Materiel Center, Philadelphia	3
Naval Air Development Center	1
Wright Air Development Division, Wright-Patterson AFB	4
Civil Aeromedical Research Institute, FAA	2
National Library of Medicine	2
Air Force Flight Test Center, Edwards AFB	2
Helicopter Utility Squadron TWO, NAS, Lakehurst	2
Aviation Research and Development Services, FAA	2
Bureau of Flight Standards, FAA	2
Bureau of Aviation Medicine, FAA	2
Bureau of Safety, CAB	2
Accident Prevention Division, U. S. Public Health Service	2
National Institutes of Health	2

U. S. Strike Command	1
U. S. Army Mobility Command	3
U. S. Army Materiel Command	8
National Library of Medicine	1

Aviation Crash Injury Research, Phoenix, Arizona, DYNAMIC TEST OF A COMMERCIAL-TYPE PASSENGER SEAT INSTALLATION IN AN H-21 HELICOPTER, L. W. T. Weinberg, J. W. Turnbow, Ph. D., TRECOM Technical Report 63-24, June 1963, 26 pp. (Contract DA-44-177-AMC-888(T) USATRECOM Task 1AO24701A12101

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An obsolete U. S. Army H-21A helicopter was remotely controlled to a crash designed (continued)

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